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Energy Independent Electric Vehicle Technology Roadmap

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Summary

Energy independent electric vehicles (EIV) are EVs that have almost unlimited range because they never need to pick up electricity. They make their own electricity from on-board solar cells etc. They should now be taken seriously as a potentially huge business and technology generator. EIVs already exist as land, water and airborne vehicles, some needing no energy storage. Investment in them is at the billion dollar level and they are already spinning off technology startups exploiting their inventions into wider markets.

Keywords: BEV (battery electric vehicle), energy source, range, vehicle performance, photovoltaic

1 Introduction

Energy independent electric vehicles (EIV) are the new end game for EVs. EIVs never pick up electricity externally: they never plug in and they never inductively charge. By definition, EIVs use on-board equipment to convert ambient energy such as sun, wind, thermals, tide and waves to create all the electricity they use for traction and other purposes.

You can buy an EIV today. The NFH-H Model NANO-SEGC-001 tourist minibus by Nonowinn Technologies in China is fitted with Nanowinn copper indium gallium diselenide CIGS thin film solar modules in the form of five 96W panels. During daylight they provide power for the motor at a claimed driving speed of 5-12 km/h without needing batteries, which become an optional extra. So here we have what you could call a lizard EIV that wakes up with the sun – an extreme form of EIV. It is not optimised: it is based on a large golf car. Imagine what will be possible if we add multiple harvesting such as an erecting wind turbine when parked, as seen in the Venturi car concepts and multiple regeneration such as regenerative braking and the 3D motion harvesting being developed by Witt and Caterpillar. Add extreme lightweighting and extreme powertrain efficiency and aerodynamics and clearly the potential for improvement of land-based EIVs is considerable.

2 EIV Aircraft and Marine Vehicles

In some ways, what is happening with EIVs at sea and in the air shows the way. Three years ago a solar boat circumnavigated the world and that is being followed by the Solar Impulse plane. It is possible with a solar car but that has yet to be demonstrated. Autonomous solar aircraft are nearly ready to stay aloft at 18.3 km/ 60,000 feet for five years on sunshine alone as a lower cost and more versatile alternative to satellites and a solar-powered surveillance airship has been designed by Northrop Grumman to make that ten years. Investment in the aircraft EIVs is already at the billion dollar level thanks to Facebook, the US Department of Defense, Boeing and others so EIVs are already a substantial business set to achieve multi-billion dollar sales in solar-powered form, but there is more.

The new Inerjy EcoVert boat, announced this year, is entirely driven by electricity from a wind turbine with vertical blades rotating around a mast – much safer than a conventional propeller shape and generating a useful 70 kW. It could add solar, wave and tidal power. The University of Bolton in the UK is developing combined photovoltaic and piezoelectric textile for sails and airship skin that will make electricity from sun, rain and motion. Sea-going yachts increasingly charge their auxiliary motor propulsion by the propellers going backwards when moored in a tidestream or under sail. That technology will improve EIVs too, indeed, those yachts could become EIVs.

Some ships are flying tethered kites to generate tens of kilowatts where it is needed, say in the bow. Tethered quadcopters have been shown to be even more effective. Analysis of these and other options are in the IDTechEx report, "High Power Energy Harvesting: 10W to 100kW 2016-2026".

3 EIVs on Land and Spinoffs

Clearly in EIVs we shall have a substantial new EV business sector. As with Formula One racing, a $15 billion business, similar or larger benefits will come from the EIV technologies spun off to general use. This has already begun with Nuon Solar Team's organisation in the Netherlands spinning off five start-ups already. They have won six out of eight Bridgestone Solar Challenges with their pancake shaped solar racers hurtling right across Australia on nothing but sunshine.

Melbourne -based start-up EVX plans to "make self-sufficient vehicles the future of transportation". It works in collaboration with the electric vehicle R&D group at Swinburne University of Technology in Australia and local solar racer engineers to commercialise the world's first road-legal solar-electric sports car, the Immortus EIV with seven square meters of highest efficiency solar skin. It will be sold at a supercar price. From the outset, like Formula One, it will develop and spin off associated technologies.

CEO Barry Nguyen states that, "We have consolidated our path to commercialization. We have also developed useful contacts with individuals who are willing to help us pilot some spin-off technologies from the solar car platform to large corporations associated with transportation in North America. The Immortus is a world first in this category. Inspired by the world portrayed in post-apocalyptic movies, the Immortus is designed to exhibit a toughness that no other car has: endurance."

Whilst designing the Immortus as a limited edition sports car powered by the sun, EVX has already identified several potential commercializable spin-off technologies. These include:

•Integrated upright system – also known as the 'hybrid retrofit kit' – enabling current petrol cars, light trucks and fleet vehicles to be converted from being petrol powered to plug-in hybrid. In addition, the kit can increase acceleration after braking and turn two-wheel drive vehicles into all-wheel drive.

•Lightweight air-cooled battery box with multi-industry applications.

•Regenerative shock absorber technology – recharging batteries from absorbing the bumps on the road, with also multi-industry applications.

Meanwhile, the Stella Lux 4 person solar car in the Netherlands, another derivative of solar racer thinking, actually donates electricity to the grid and it claims a unique in its traction motor. Most electric motors run at about 80 percent energy efficiency. A really good one might top 85%, or approach 90% like that in the Tesla. Stella Lux claims a 97% efficient PM motor,albeit for an undemanding duty cycle. The modules have both high rated-power and power conversion efficiency; thus easily generating power with visible light. Clearly this can be useful beyond EIVs.

The Resolution solar racer of Cambridge University in the UK tracks the sun using GaAs solar panels, bringing spacecraft technology down to earth. Gallium arsenide cells are both lighter and more efficient than silicon-based variants. This 4.5m-long, teardrop-shaped car produces 1.5kW of power – the same as a hair dryer – but is capable of a top speed of about 137 kph/ 85mph. Again, a useful proof of a technology relatively new in land vehicles and with wide implications. It uses low rolling resistance tyres that are designed specifically for solar powered cars but may find other uses too.

4 Heavy Duty EIVs

Those arguing that EIVs are so weak and feeble that they will remain a sideshow have to be reminded that the Turanor boat that went round the world could carry heavy cargo and a Canadian heavy-lifting aircraft has just received further funding. Designed as an EIV in the form of a large helium-filled aerofoil, it is propelled entirely by solar power from its skin. The wider benefits of EIV technology are coming thick and fast.

5 Roadmap 2016-2026

To support this potentially huge new business, IDTechEx has prepared two new reports, the overview "Energy Independent Vehicles 2016-2026" and the drill down, "Energy Independent Electric Vehicle Technology Roadmap 2016-2036".

Some extracts from the IDTechEx roadmap are shown below.

Table 1. EIV technology roadmap 2016-2036, abridged version [1]

<table>
<tr><th></th><th>2016</th><th>2017</th><th>2018</th><th>2019</th><th>2020</th><th>2021</th><th>2022</th><th>2023</th><th>2024</th><th>2025</th><th>2026</th><th>2036</th></tr>
<tr><td>General</td><td colspan="2">Electric vehicles are mainly "born electric" not modified from a vehicle not intended for that purpose. Examples: Tesla S, BMW i3</td><td colspan="4">EIV technology is used on micro EVs to an increasing extent though most are not yet true EIVs. Combinations of EIV technology and dynamic road charging trialled extensively</td><td colspan="2">EIVs are "born EIV" Many land, water and air autonomous vehicles demonstrated that are EIV</td><td colspan="3">Boats and ships combining electrical and mechanical EIV technology. Origami and other self-assembly EIVs using smart materials – structural electronics. Lizard EIVs suitable for mass production, with a self-charging Night Module you pop in to travel when sun is not shining.</td><td>Tens of millions EIV yearly helps remote regions/ third world. EIV technology spinoffs create >$10 bn</td></tr>
<tr><td>External energy harvesting</td><td colspan="6">For land and air vehicles, little beyond photovoltaics which moves more to single crystal silicon and GaAs, conformal. For boats and ships – wave, tide, sun and wind power and early rollout of Witt 6D motion harvester initially in low power form. Fresnel lens overlayer on high efficiency conformal lightweight PV giving up to 44% efficiency.</td><td colspan="5">Multiple energy harvesting more common e.g. adding wave, tide, wind power for traction and aircraft flying into thermals to generate electricity by the propeller going backwards. Autonomous underwater vehicles (AUVs) with multi-mode energy harvesting become common.</td><td>Stretch PV and

spray PV on EIVs including retrofit</td></tr>
<tr><td>Powertrain</td><td colspan="6">Exceptionally high efficiency in-wheel motors increasingly used with direct drive. Increased use of supercapacitor, SiC and GaN power components for higher efficiency sometimes permitting no water cooling.</td><td colspan="3">Many more autonomous EIVs. Many more systems around 700V and 800V for efficiency and lower overall cost of vehicle.</td><td colspan="3">Multi-mode external and internal energy harvesting increasingly permits no battery. Increasing use of mechanical EH (sails etc.) as well will assist in this.</td></tr>
<tr><td>Light

weighting</td><td colspan="3">Increasing use of carbon fiber, aluminium, composites. Great simplification of drive trains. Higher power to weight ratio motors</td><td colspan="4">Large volumes of micro EV classified EIVs on land – too fragile for crash testing. 3D printing of structures such as those like a bird's bones in production e.g. car seats, aircraft. Heating and cooling the passenger not the space.</td><td colspan="5">Structural electronics in racers and some other EIVs e.g. supercapacitor and solid battery as protective skin or load-bearing parts saving weight and space. Mechanical harvesting of oncoming waves used in ships for lifting them in the water, reducing drag. Widespread use of helium filled fixed wing unmanned aerial vehicles (UAVs) as EIVs.</td></tr>
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References

[1] P.Harrop, *Energy Independent Electric Vehicle Technology Roadmap 2016-2036: Markets and key technologies including extreme powertrain efficiency, energy harvesting and lightweighting*, IDTechEx, 2015

Authors

Dr Peter Harrop PhD, FIEE is Chairman of IDTechEx Ltd. He was previously Director of Technology of Plessey Capacitors Scotland and Chief Executive of Mars Electronics, a start-up he took to $260 million gross sales value with highly automated factories built in US and UK, without acquisitions. He was a board member of $1.5bn Mars UK, a division of Mars Inc. Mars Electronics was sold for $500 million after he left, generating an excellent return. He has been Chairman of 15 high tech companies over a period of years including turnrounds on behalf of venture capitalists such as Computer Security International. The largest was Pinacl plc in Wales, made profitable and grown to $100 million in fiber optic manufacture and multimillion dollar structural networks. Peter lectures and consults internationally on electric vehicles, energy storage, RFID and printed/organic electronics. He writes a number of techno-marketing reports yearly at IDTechEx.